Pleistocene wave-built terraces of Northern Rio de Janeiro State, Brazil

13

LOUIS MARTIN
ORSTOM – Centre de Bondy, Bondy, Cedex, France
JEAN-MARIE FLEXOR
Observatório Nacional/CNPq, Rio de Janeiro, Brazil
KENITIRO SUGUIO
Instituto de Geociências/USP, São Paulo, Brazil

ABSTRACT: Previous studies of a great portion of eastern and southeastern coasts of Brazil have frequently shown the presence of two distinct generations of sandy terraces of marine origin. The most recent is Holocene in age, being related to the last sea-level rise, whose maximum elevation was attained about 5100 years BP. The most ancient is Pleistocene in age, being related to the penultimate sea-level rise, whose culmination stage occurred about 123,000 years BP. In Northern Rio de Janeiro State, these two generations of marine terraces are present. However, it has not been possible yet to obtain absolute ages of these sandy deposits.

RESUMO: Os estudos prévios de grande trecho das costas leste e sudeste do Brasil mostraram freqüentemente a presença de duas gerações distintas de terraços arenosos de origem marinha. O mais recente é de idade holocênica, estando relacionado à última subida de nível do mar, cujo máximo ocorreu há aproximadamente 5100 anos AP. O mais antigo é de idade pleistocênica, estando ligado à penúltima subida de nível do mar, cujo máximo foi verificado há cerca de 123,000 anos AP. Na porção norte do Estado do Rio de Janeiro, essas duas gerações de terraços marinhos estão presentes, embora não tenha sido possível obter as idades absolutas desses depósitos arenosos.

1 INTRODUCTION

Studies performed along the Brazilian coast, during the last decades, indicated the existence of records related to several high sea-levels during the Quaternary (Villwock et al. 1986, Martin et al. 1988). The most recent is quite well known thanks to numerous radiocarbon dates, which have allowed to delineate relative sea-level fluctuation curves during the last 7000 years, for several sectors of the Brazilian coast. In spite of their dif-

ferences in amplitude, these curves show an essential fact that, during the last 7000 years, the relative sea-level was higher than the present in most part of the Brazilian coastline. This coast was under submergence conditions until about 5100 years BP, but it reversed into emergence after 5100 years BP, with the intercalation of brief submergence episodes (Suguio et al. 1985, Martin et al. 1987).

Evidence of the penultimate high sea-level position is given by huge sandy terraces extending, at least, from the Paraíba State to the Rio Grande do Sul State. The marine origin of these sandy deposits is confirmed by the presence of fossilized *Callichirus* burrows (Suguio & Martin 1976, Suguio et al. 1984), as well as by the occurrence of typical syngenetic sedimentary structures (Suguio & Tessler 1987, Tessler & Suguio 1987). At the surface of these terraces there are ancient beach-ridge alignments, with some differences when compared with the Holocene terraces (Martin et al. 1981). These sands are in general whitish in surface but in subsurface they may show a dark brownish colour due to humic and/or fulvic acids impregnation. In opposition to the Holocene terraces, where mollusk shells are frequently found, they are absent in the Pleistocene terraces, probably because they were dissolved by organic acids (Dehira & Suguio 1994). However, preserved shells were sampled from a clayey layer at the base of a Pleistocene terrace, which gave a radiocarbon age older than 30,000 years BP. In Brazil, only in one location in southern Bahia State, more-or-less preserved coral samples have been randomly collected from the basal portion of a Pleistocene terrace. They belong to the genus *Siderastrea* and only five of them, composed of pure aragonite, have been dated by the uranium/ionium method (Martin et al. 1982).

Samples CP-1, CP-2, CP-6 and CP-8 indicated ages close to their overall mean: 123,500 + 5700 years BP. Only sample CP-7 showed an age significantly older, probably due to slight contamination. Therefore, it is possible to assume that the maximum of the penultimate high sea-level occurred about 123,000 years BP, in agreement with available data from the majority of localities around the world.

In most of Brazilian eastern and southeastern coastlines the relative sea-level corresponding to this transgressive episode is situated 8 ± 2 m above the present level. Nevertheless, in some sectors like in the Todos os

Table 1. U/Io dates of coral samples from the State of Bahia (Martin et al. 1982).

Sample	$^{234}U / ^{238}U$	U(ppm)	^{234}U(dpm/g)	Io(^{230}Th)(dpm/g)	Age(yr BP)
CP-1	1.07	2.59	2.08	1.43	122,000 ± 6100
CP-2	1.08	2.70	2.17	2.42	116,000 ± 6900
CP-6	1.11	3.09	2.57	1.85	132,000 ± 9000
CP-7	1.11	2.58	2.14	1.61	142,000 ± 9700
CP-8	1.08	2.56	2.30	1.60	124,000 ± 8700

Santos Bay (State of Bahia), these records could be lower as a consequence of modern tectonic movements (Martin et al. 1984a).

2 RECORDS OF THE 123,000 YEARS BP HIGH SEA LEVEL AT NORTHERN RIO DE JANEIRO STATE

A preliminary geologic mapping of the Quaternary deposits was enough to make evident the existence of at least two distinct generations of sandy marine terraces in several sectors of the northern Rio de Janeiro State (Fig. 1). Despite the absence of absolute datings, some arguments based on previous experience allow to suggest that the higher terraces are probably Pleistocene in age. Considering the inadequacy of the radiocarbon dating method, as well as the absence of adequate samples for U/Io dating, the following criteria have been used:

a) ages beyond the reliability of the radiocarbon method (more than 30,000 years BP);

b) morphological features of the deposits, particularly the alignment characteristics of the ancient beach-ridges;

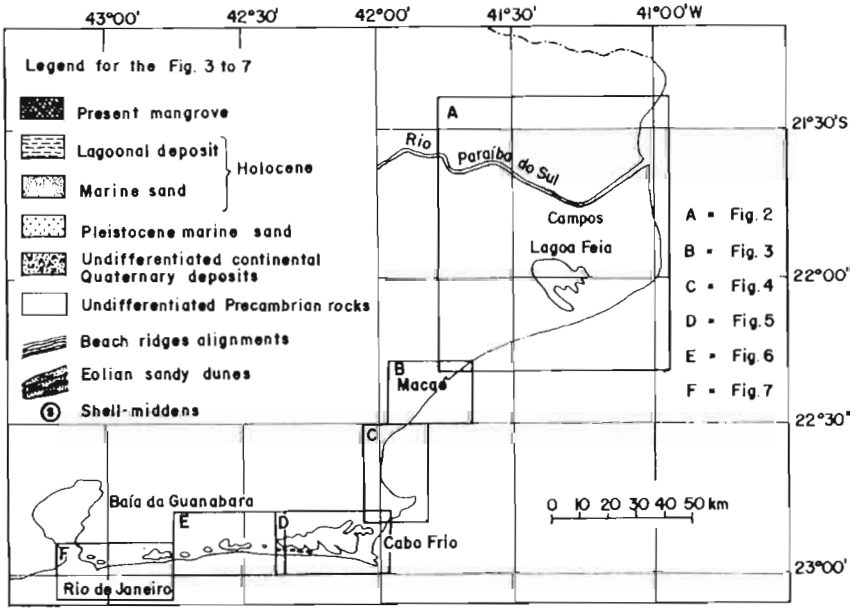

Figure 1. Location map of the studied area, geographical position corresponding to Figures 2-7 and legend (Figs 3-7) of the maps.

c) the absence of mollusk shells, and sands commonly impregnated by humic and/or fulvic acids with a slight cohesion;

d) their positions in the coastal plain, as well as their heights; and,

e) overconsolidation of clay beds beneath the sands (Massad 1985).

Previous works revealed that in the coastal plain of the Rio Paraíba do Sul estuary (Fig. 2) there are two distinct generations of sandy wave-built terraces (Martin et al. 1984b, 1987). In its southern portion, between Ma-

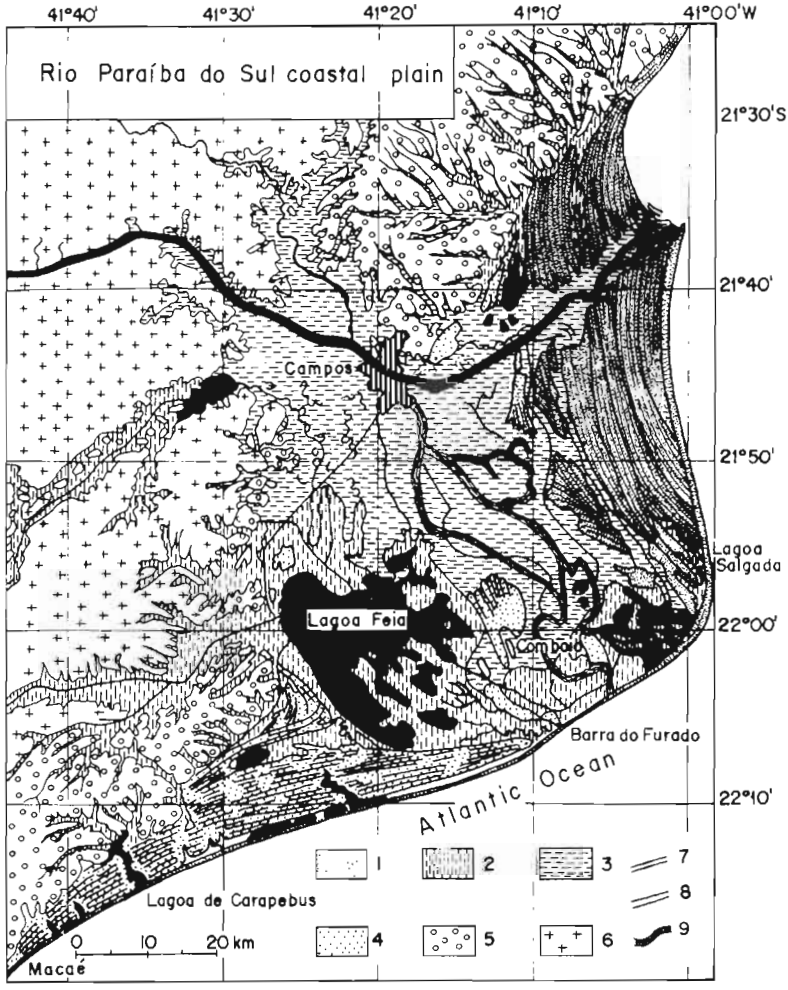

Figure 2. Schematic geologic map of the Rio Paraíba do Sul coastal plain. 1. Holocene marine terrace, 2. lagoonal sediments, 3. fluvial sediments (intralagoonal delta), 4. Pleistocene marine terrace, 5. Barreiras Formation, 6. Precambrian rocks, 7. alignments of Pleistocene beach-ridges, 9. palaeochannels of the Rio Paraíba do Sul (from Martin et al. 1987).

caé and Barra do Furado, there is a narrow sand barrier landward from the sea, followed by an almost desiccated lagoonal lowland and an extensive sand flat overlying Barreiras Formation or Precambrian crystalline rocks.

The morphological characteristics of the regressive beach-ridges covering this terrace is quite different from the beach-ridges found around the Rio Paraíba do Sul outlet and, on the other hand, perfectly comparable to that occurring at southern Bahia State. Moreover, it is possible to recognize that the surface of this terrace was intensively dissected by a drainage net during the last Pleistocene relative low sea-level (i.e., Oxygen Isotope Stages 2-4). For example, the Lagoa de Carapebus (Fig. 2) is situated in a valley excavated within this terrace, and was subsequently drowned during the last relative sea level-rise. Obviously, this valley was formed before 7000 years BP, when the present sea-level was overpassed during the last transgression.

Radiocarbon ages of 6590 ± 250, 6620 ± 240, 6000 ± 230 and 5930 ± 240 years BP, obtained in mollusk shells sampled from lagoonal deposits situated between sandy beach-ridges, suggest that the inland deposits covered by regressive beach-ridges are older than 7000 years BP (Martin et al. 1984b). In the remaining portion of the coastal plain, always situated landward of the Holocene deposits, there are more-or-less eroded records of these ancient deposits. Thus, in the Comboio region, at the center of the Rio Paraíba do Sul outlet coastal plain (Fig. 2), the elongated lowlands within sandy deposits correspond to areas situated between ancient beach-ridges, which were partially excavated during the last sea-level drop. These sandy deposits cannot be called chêniers, as it was done by Dias (1981), because they are not covering clayey sediments. A radiocarbon age of 6000 ± 200 years BP, obtained from mollusk shells sampled from lagoonal deposits, is also indicating that the fluvial excavation was before 7000 years BP, and the drowning of the lowlands occurred during sea-level rise. Considering that in this area only two Quaternary high sea-levels have been recognized until today and that the most recent is Holocene in age, it is possible to draw the conclusion that the older ancient deposits must correspond to the high sea-level of 123,000 years BP.

The Pleistocene marine deposits forming an essential part of the southern coastal plain of the Rio Paraíba do Sul extend until north of the site of Macaé. However, from the Lagoa de Carapebus to Macaé (Fig. 2), the intermediate lowland disappears and the Holocene deposits are reduced to present beaches, which have a tendency to advance over the Pleistocene sands; as they have different colours, this phenomenon is clearly visible. The lower elevation of the Pleistocene terrace seems to suggest that this area was under permanent subsidence during the Quaternary. This hypothesis is apparently confirmed by a gravimetric anomaly indicated in the Bouguer map of the area (Martin et al. 1984b).

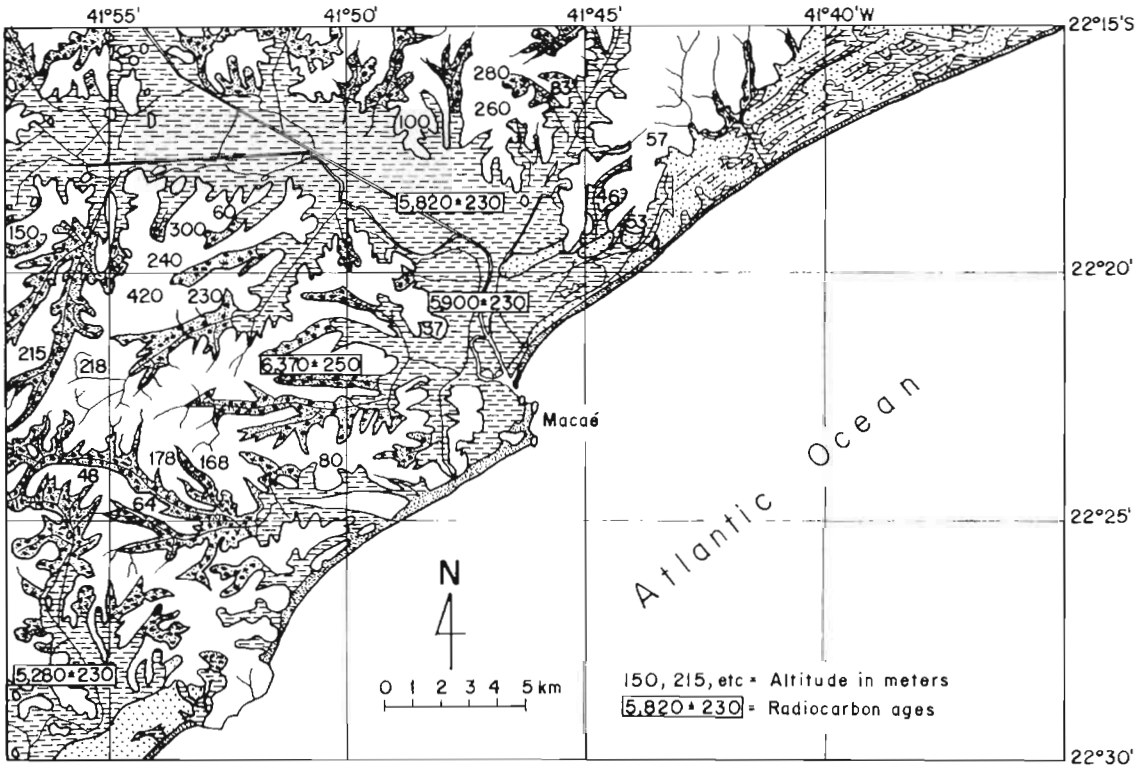

Figure 3. Schematic geologic map of the Macaé region.

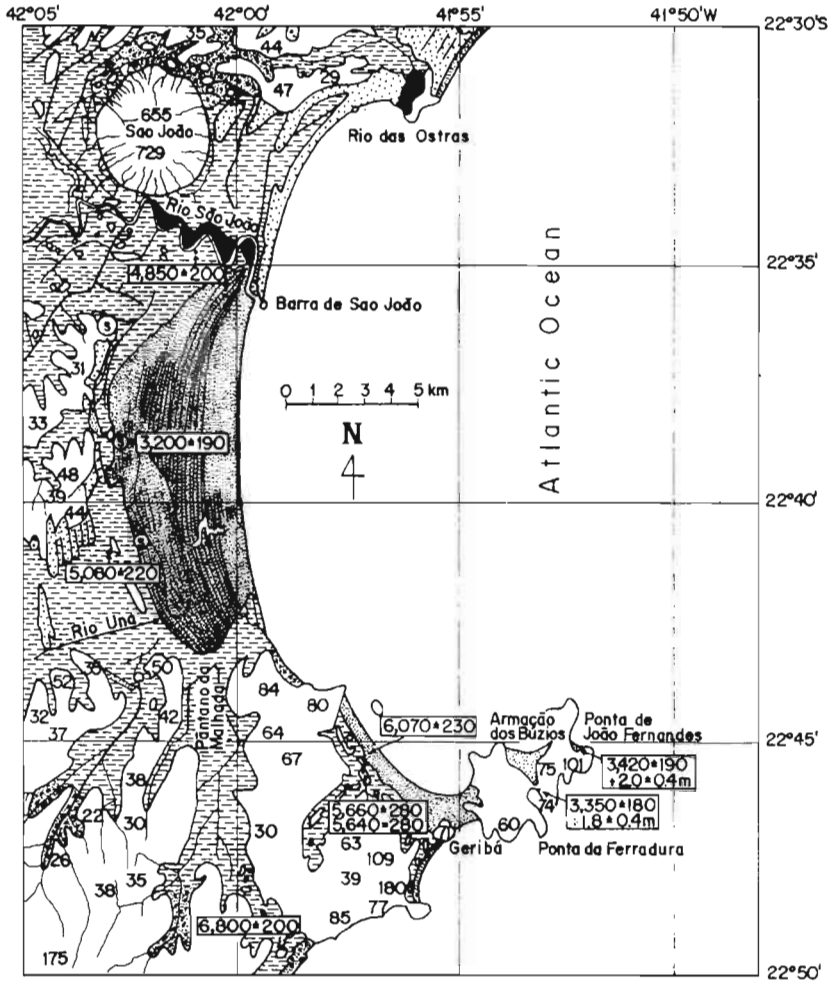

Figure 4. Schematic geologic map of the Barra de São João region.

In the Rio das Ostras area (Figs 3 and 4), most of the sandy terraces are assigned to the Pleistocene. To the north, these deposits are relatively important, and the Lagoa Salgada shows morphological characteristics typical of a lagoon installed within a zone excavated during a sea-level lower than the present, and invaded during the transgression. Between Rio das Ostras and Barra de São João, the Pleistocene deposits are reduced to a narrow band in the oceanic margin besides some continental remains, frequently impregnated by humic and/or fulvic acids. In this area, the Holocene deposits are represented only by the present beaches.

In the internal portion of the large valleys excavated by the Rio São

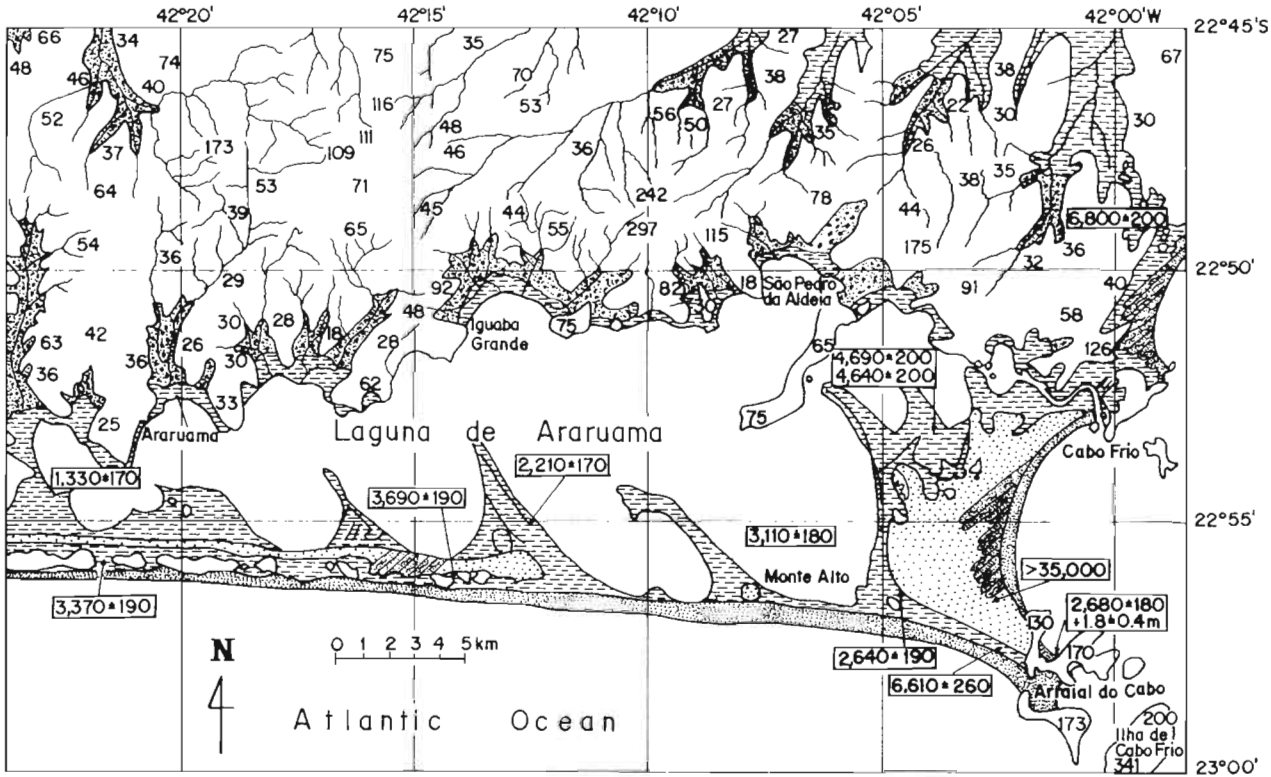

Figure 5. Schematic geologic map of the Araruama lagoon region.

João and the Rio Una (Fig. 4), similarly as it takes place in the Rio Itabapoana valley in the limit of the states of Rio de Janeiro and Espírito Santo, there are two generations of sandy marine terraces. The external deposits are more developed and covered by typical Holocene beach-ridges. More inlandwards, there are eroded relicts of Pleistocene terraces.

Between Cabo Frio and Arraial do Cabo (Fig. 5), most of the sandy deposits are of Pleistocene age. This statement is based on a radiocarbon date of more than 30,000 years BP, obtained from a wood fragment sampled in a sand with abundant impregnation by organic matter. These Pleistocene deposits are partially covered by Holocene aeolian dunes and they were preserved from erosion during the last transgression behind crystalline rock hills of the Arraial do Cabo.

From Arraial do Cabo to Niterói (Figs 5, 6 and 7) there are, frequently, two sandy barriers separated by a depression, sometimes occupied by small lagoons, like the Lagoa Vermelha (Fig. 6). Muehe (1982) and Coe Neto et al. (1986), based on relative sea-level fluctuation curves proposed by Suguio & Martin (1981) and Martin et al. (1983), assigned a Holocene age for both units. The inner barrier would have been formed during the high sea-level of 5100 years BP, and the second could be related to the high sea-levels of 3600 and 2500 years BP (Coe Neto et al. 1986). However, a sample of mollusk shells collected from the bottom of Lagoa Vermelha indicated a radiocarbon age of 4830 ± 280 years BP. This age shows that the lagoon and, consequently, the external barrier is older than 5000 years BP. Moreover, drilling made in the eastern extreme lowland of the Brejo do Espinho attained an organic matter saturated sand, probably Pleistocene in age, at a depth of 3 m. Finally, in the Praia Seca area, there are outcrops of organic matter saturated sand from the internal barrier.

On the other hand, in the Itaipu-Açu area, Ireland (1987), in his work on the sedimentary history of the lagoons in this region, stated: 'It is clear that the present barrier (external barrier) is older than 2770 years BP. It is suggested that the fossil barrier (internal barrier) and the sedimentary sequence behind it is Pleistocene in age. This formation is considered to be related to the Cananéia Formation which has been described in São Paulo State...'

3 CONCLUSIONS

In the absence of absolute ages, it seems reasonable to attribute a Holocene age to both sandy barriers occurring between Arraial do Cabo and Itaipu-Açu (Muehe 1982, Coe Neto et al. 1986), like the barriers found in the Jacarepaguá coastal plain (Maia et al. 1984). The relative sea-level oscillations during the last 7000 years, which are clearly exposed in deposits

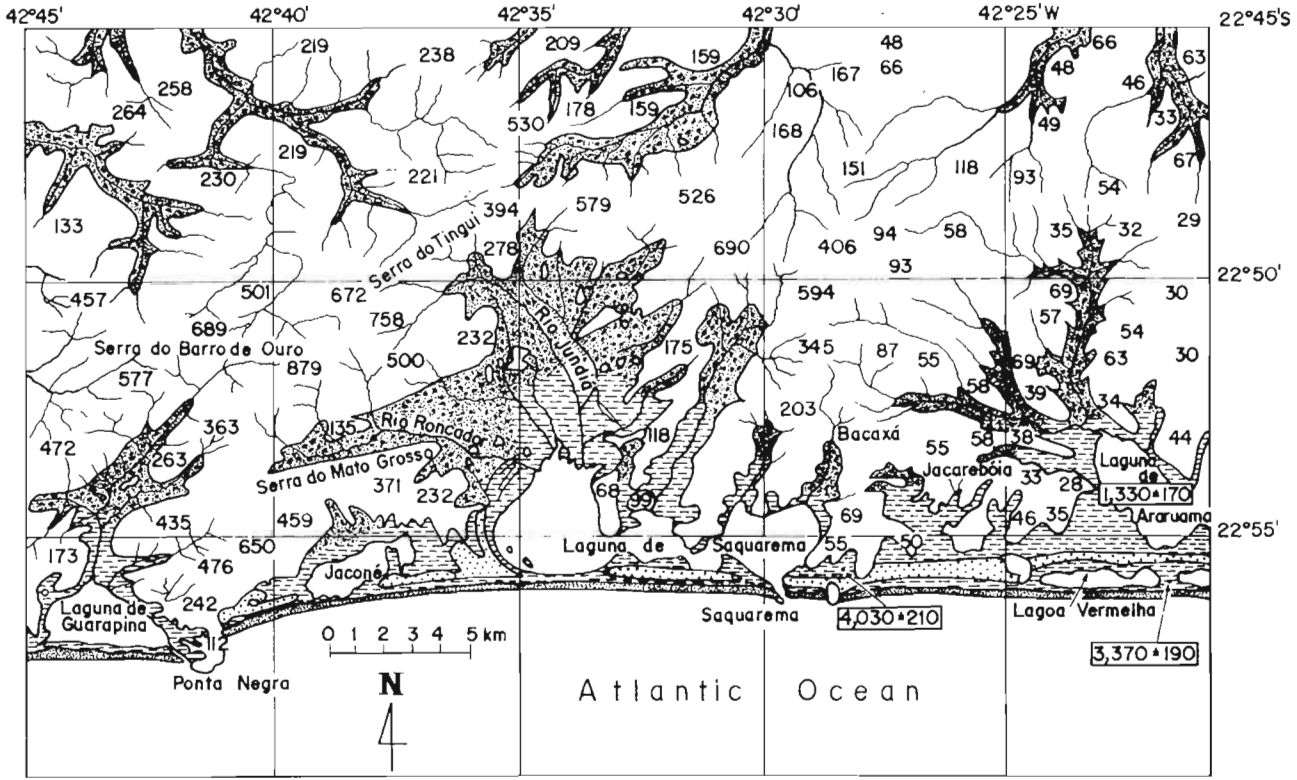

Figure 6. Schematic geologic map of the Saquarema lagoon region.

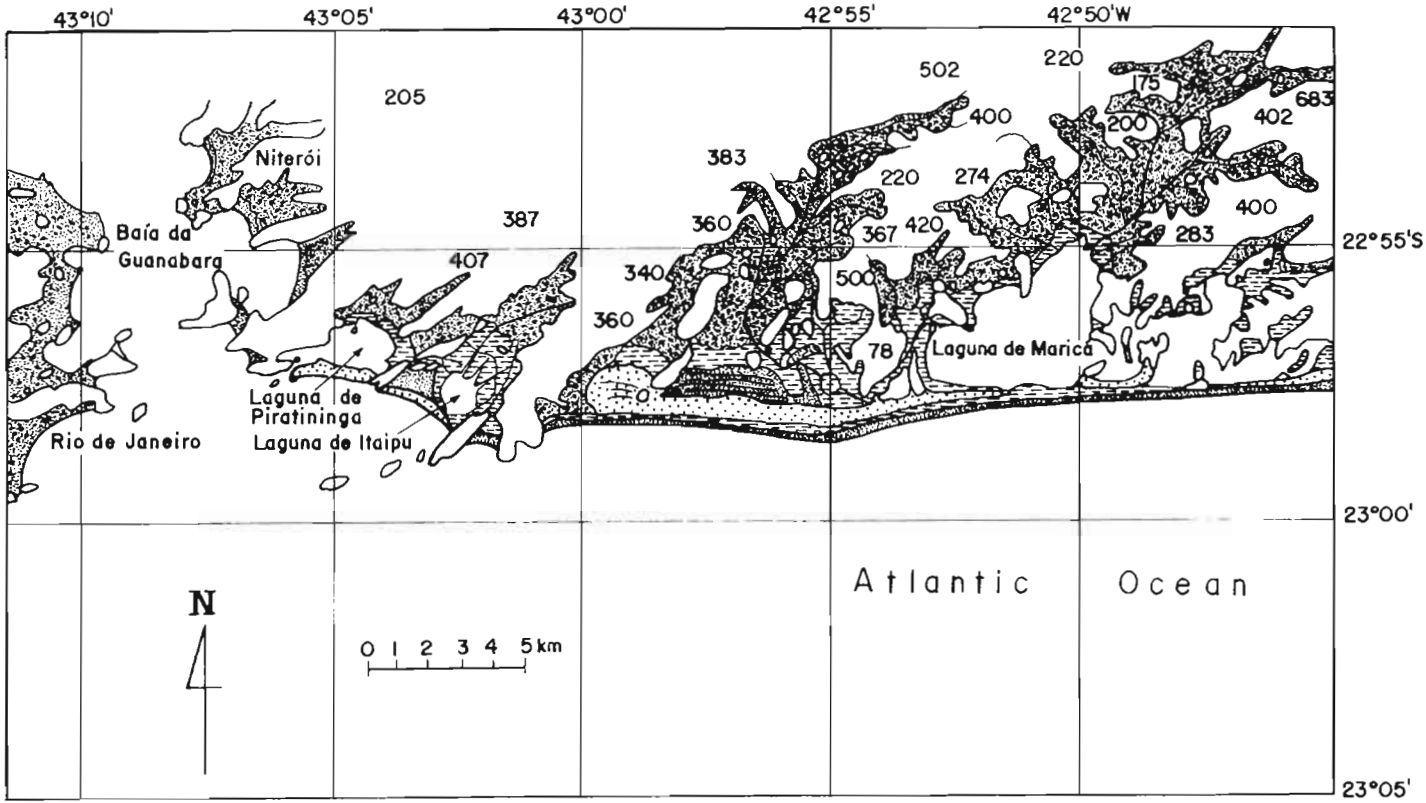

Figure 7. Schematic geologic map of the Maricá lagoon region.

in other sectors of the Brazilian coast, may explain the construction of two barriers separated by a lagoonal zone.

From this viewpoint, the internal barrier would have been formed during the terminal portion of the last transgression, whose culmination stage was about 5100 years BP, whereas the external barrier would have been built about 3600 years BP. In fact, a rapid examination of the preliminary ages seem to confirm this hypothesis.

However, new ages compared with a certain number of other data suggested that only the external barrier is Holocene, whereas the internal barrier is Pleistocene, and related to the high sea-level of 123,000 years BP. Consequently, the large lagoons (Araruama, Maricá and Saquarema) were settled at the places of ancient Pleistocene lagoons, similarly to those that existed in the states of Santa Catarina and Rio Grande do Sul. Moreover, most of the marine deposits found between Cabo Frio and São Tomé are also Pleistocene in age.

REFERENCES

Coe Neto, R., J.M. Froidefond & B. Turcq 1986. Géomorphologie et chronologie relative des dépôts sédimentaires récents du littoral brésilien a l'est de Rio de Janeiro. *Bull. Inst. Géol. Bassin d'Aquitaine*, 40: 67-83, Bordeaux, France.

Dehira, L.K. & K. Suguio 1994. Moldes de conchas fósseis de pelecípode na Formação Cananéia, Pleistoceno Marinho do Estado de São Paulo. *38° Congresso Brasileiro de Geologia*, Resumos expandidos: 219-220. Balneário Camboriú (SC), Brazil.

Dias, G.T.M. 1981. O complexo deltaico do Rio Paraíba do Sul. *IV Simpósio do Quaternário no Brasil*, Publicação Especial 2: 38-88, Rio de Janeiro. Brazil.

Ireland, S. 1987. The Holocene sedimentary history of the coastal lagoons of Rio de Janeiro State, Brazil. In: M.J. Tooley & I. Shennan (Eds), *Sea-level changes: 25-65*, London: *Basil Blackwell.*

Maia, M.A.C., L. Martin, J.M. Flexor, A.E.G. Azevedo 1984. Evolução holocênica da planície costeira de Jacarepaguá, R.J.: Influência das variações do nível do mar. *Anais do XXXIII Congresso Brasileiro de Geologia*, 1: 105-118. Rio de Janeiro. Brazil.

Martin, L., A.C.S.P. Bittencourt, G.S. Vilas-Boas 1981. Différentiation sur photographies aériennes des terrasses sableuses marines pléistocènes et holocènes du littoral de l'état de Bahia, Brésil. *Photointerprétation* 3, fasc. 4/5. Paris.

Martin, L., A.C.S.P. Bittencourt & G.S. Vilas-Boas 1982. Primeira ocorrência de corais pleistocênicos da costa brasileira: datação do máximo da penúltima transgressão. *Ciências da Terra* 1: 16-17, Salvador, Bahía. Brazil.

Martin, L., J.M.L. Dominguez, K. Suguio, A.C.S.P. Bittencourt & J.M. Flexor 1983. Schéma de la sédimentation quaternaire sur la partie centrale du littoral brésilien. *Cahiers ORSTOM, Sér. Géol.* 8(1): *59-81.* Paris.

Martin, L., A.C.S.P. Bittencourt, J.M. Flexor, G.S. Vilas-Boas 1984a. Evidência de um tectonismo quaternário nas costas do Estado da Bahia. *Anais do XXXIII Congresso Brasileiro de Geologia* 1: 19-35. Rio de Janeiro.

Martin, L., K. Suguio, J.M.L. Dominguez, J.M. Flexor, A.E.G. Azevedo 1984b. Evolução da Planície Costeira do Rio Paraíba do Sul durante o Quaternário: Influência das variações do nível do mar. *Anais do XXXIII Congresso Brasileiro de Geologia* 1: 84-97. Rio de Janeiro.

Martin, L., K. Suguio, J.M. Flexor, J.M.L. Dominguez & A.C.S.P. Bittencourt 1987. Quaternary evolution of the central part of the Brazilian coast. The role of relative sea level variation and of shoreline drift. *UNESCO Reports in Marine Science* 43: 97-145.

Martin, L., K. Suguio & J.M. Flexor 1988. Hauts niveaux marins pléistocènes du littoral brésilien. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 68(2/4): 231-239.

Massad, F. 1985. *Progressos recentes dos estudos sobre as argilas quaternárias da Baixa- da Santista*. Associação Brasileira de Mecânica dos Solos (ABMS). São Paulo. 21 pages.

Muehe, D. 1982. The coastline between Niterói and Ponta Negra. *International Geographical Union. Commission on Coastal Environment Field Trip*: 23-27. Rio de Janeiro.

Suguio, K. & L. Martin 1976. Presença de tubos fósseis de *Callianassa* nas formações quaternárias do litoral paulista e sua utilização na reconstrução paleoambiental. *Boletim IG, Instituto de Geociências,* Vol. 7: 17-26, São Paulo.

Suguio, K. & L. Martin 1981. Progress in research on Quaternary sea-level changes and coastal evolution in Brazil. *Proceedings of the Symposium: Holocene Sea Level Fluctuations, Magnitude and Causes*. Department of Geology, University of South Carolina, 166-181, Columbia, USA.

Suguio, K. & M.G. Tessler 1987. Characteristics of a Pleistocene nearshore deposit: an example from southern State of São Paulo coastal plain. *Quaternary of South America and Antarctic Peninsula* 5: 257-268. Rotterdam: Balkema Publishers.

Suguio, K., S.A. Rodrigues, M.G. Tessler & E.E. Lambooy 1984. Tubos de 'ophiomorphas' e outras feições de bioturbação na Formação Cananéia, Pleistoceno da planície costeira Cananéia-Iguape. In: L.D. Lacerda et al. (orgs.) *Restingas: origem, estruturas, processos:* 111-122. Niterói, Rio de Janeiro, Brazil.

Suguio, K., L. Martin, A.C.S.P. Bittencourt, J.M.L. Dominguez, J.M. Flexor & A.E.G. Azevedo 1985. Flutuações do nível relativo do mar durante o Quaternário Superior ao longo do litoral brasileiro e suas implicações na sedimentação costeira. *Revista Brasileira de Geociências* 15(4): 273-286.

Tessler, M.G. & K. Suguio 1987. Características sedimentológicas da Formação Cananéia (Pleistoceno Superior) na área de Paranaguá-Antonina (Estado do Paraná, Brasil). *Proceedings of the IGCP-Project 201 (Quaternary of South America) meeting*: 43-54. Mérida, Venezuela.

Villwock, J.A., L.J. Tomazelli, E.L. Loss, E.A. Dehnhardt, N. Horn Filho, F.A. Bachi & B.A. Dehnhardt 1986. Geology of the Rio Grande do Sul Coastal Province. *Quaternary of South America and Antarctic Peninsula* 4: 79-97. Rotterdam: Balkema Publishers.

FROM THE SAME PUBLISHER:

Rabassa, Jorge (ed.) ISSN 0168-6305
Quaternary of South America and Antarctic Peninsula
1983-, 23 cm, c.160 pp., Hfl.140 / $70.00 / £47 per volume
Emphasis is on the paleoenvironmental & paleoclimatic approach. Helps to correlate S.American environmental events & endogenous episodes with equivalents in other parts of the world. Editor: Director Cadic, Ushuaia.

Bobrowsky, P.T. 90 5410 675 1
Aggregate resources – *A global perspective*
1998, 25 cm, 480 pp., Hfl.190 / $95.00 / £63
This book provides a comprehensive collection of 27 diverse scientific papers on aggregate topics such as geology of deposits, geophysical exploration techniques, deposit prediction and modeling, land-use case studies, production values and trends, geotechnical properties, legislation politics and others. This diversity in subject matter is further enhanced by relying on contributions from a number of countries including Australia, Belgium, Canada, Lebanon, Netherlands, Norway, South Africa, United Kingdom and the United States. The range of topical papers & representative countries, coupled with the global significance of the resource prompted the title Aggregate Resources: A global perspective. This book will appeal to all those involved with aggregate resources: Geologists, producers, construction engineers, technicians, developers, land-use planners, legislators, academics and the public consumer, especially since all of us are in some manner either, directly dependent or indirectly affected by this resource.
*Each chapter is a study on a particular area of importance for aggregate producers. *Pit & Quarry*, April 1998.

Lingen, G.J.van der, K.M.Swanson & R.J.Muir (eds) 90 5410 328 0
Evolution of the Tasman Sea Basin – *Proceedings of the Tasman Sea conference, Christchurch, New Zealand, 27-30 November 1992*
1994, 25 cm, 272 pp., Hfl.180 / $90.00 / £60
A wide range of topics is covered, providing an up-to-the-minute assessment of the state of knowledge on the Tasman Sea Basin. The papers deal with the geological & geophysical aspects of Gondawa break-up (opening of the Tasman Sea), including hot-spot-trails, granite emplacement, paleomagnetism & rifted-marginal basins; Paleooceanography, including atmospheric & oceanic circulation patterns; Detailed examinations of oxygen-isotope records, distribution patterns & dissolution records of marine fauna, providing new paleoclimatic & paleogeographic information relating to geologically most recent evolutionary history of Tasman Sea Basin.

Alsharhan, A.S., K.W.Glennie & G.L.Whittle (eds.) 90 5410 597 6
Quaternary deserts and climatic change – *Proceedings of an international conference, Al Ain, 9-11 December 1995*
1998, 25 cm, 636 pp., Hfl.195/ $99.00 / £65
These proceedings record the results of climate change in many areas that today are hyper-arid deserts, but which, almost cyclically, at intervals of thousands and even hundreds of thousands of years ago had a much more humid climate. The book is divided into following broad sections: Quaternary climatic changes; Quaternary sedimentation and diagenesis; Hydrogeology and geochemical applications to Quaternary deserts; Quaternary analogs to ancient and remote sediments; Dunes and inland sabkhas; Fluvial and wadi systems; Remote sensing and archaeology.

Rengers, Niek (ed.) 90 5410 398 1
Engineering geology of Quaternary sediments – *Proceedings of the 20-year jubilee symposium of the INGEOKRING, 3 June 1994, Delft, Netherlands*
1994, 25 cm, 154 pp., Hfl.100 / $50.00 / £33
8 keynote lectures by Dutch specialists at the 20-year jubilee symposium of the Netherlands Ingenieursgeologische Kring. *Topics*: Developments in engineering geology in the Netherlands; Engineering geophysical data colllection techniques; Unconventional sounding & sampling techniques; Classification & characterization of soft soils; Geostatistics in holocene deposits; Modelling of unconsolidated sediments; Environmental engineering geology; The use of underground space in deltaic areas.

Warren, P.J. & D.G.Croot (eds.) 90 5410 096 6
Formation and deformation of glacial deposits – *Proceedings of the Meeting of the Commission of Glacial Deposits, Dublin, Ireland, May 1991*
1994, 25 cm, 232 pp., Hfl.120 / $60.00 / £40
Formation of Diamictons (glacial versus non-glacial); Formation of sorted glacigenic sediments; Interpreting the glacial record. The papers encapsulate the work of the sponsoring INQUA Commission and its predecessor, focussing scientific analysis on questions of till genesis and its interpretation of depositional processes and environments. Editors: University of Plymouth, UK.

Kujansuu, R. & S.M.Saarnisto (eds.) 90 6191 857 X
Glacial indicator tracing
1990, 25 cm, 160 pp., Hfl.150 / $75.00 / £50
Methods (Field & laboratory methods; Air photo interpretation; Geophysical methods; Geochemical methods; Automatic data handling); *Glacial geology of indicator tracing* (Genesis; Morphology; Boulder transport; Lithology; Indicator tracing in the mountain glacier environment; Trace metals & heavy minerals in glacial material). Editors: Geological Survey of Finland.

All books available from your bookseller or directly from the publisher:
A.A. Balkema Publishers, P.O. Box 1675, NL-3000 BR Rotterdam, Netherlands (Fax: +31-10-413-5947)
For USA & Canada: A.A. Balkema Publishers, Old Post Rd, Brookfield, VT 05036-9704 (Fax: 802-276-3837)

Martin Louis, Flexor J.M., Suguio K (1998)

Pleistocene wave-built terraces of northern Rio de Janeiro state, Brazil

In : Rabassa J. (ed.), Salemme M. (ed.) Quaternary of South America and antartica peninsula : vol. 11. Rotterdam : A.A. Balkema, 233-245

ISBN 9054104538